Haptics, haptic devices

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"*Haptics is used as an umbrella term covering all aspects of manual exploration and manipulation by humans and machines, as well as interactions between the two, performed in real, virtual or teleoperated environments. Haptic interfaces allow users to touch, feel and manipulate objects simulated by virtual environments and teleoperator systems.*" [Biggs, Srinivasan, 2002] – quoted by E. Pasquinelly in [→ Haptics, in cognitive sciences].

Indeed, the term haptic devices (or haptic interfaces) covers very diverse technologies and systems. This term is now commonly used by a wide professional community (including interactive robotics, teleoperation and human-computer interfaces, and… the field of haptics). However, we assume that it is not sufficiently precise to be helpful. This includes all the electromechanical actuating systems able to stimulate any part of the haptic perceptual system, eventually correlated with electromechanical sensing systems to acquire data on human's gestures and movements. Indeed, as a preliminary remark, a haptic device comprehends necessarily an actuator, which role is to stimulate human haptic perceptual system.

A today's usual classification of haptic devices is: tactile devices, force feedback devices and haptic display.

Pragmatically, tactile devices [→ Tactile device] stands for the electromechanical actuators able to stimulate the mechanoreceptors situated on and under the skin. And Force feedback devices stands for the devices embedding sensors and actuators. Here, the word feedback is essential: it means that the force produced by the actuator depends on the data sensed by the sensors. As for them, haptic displays (or force displays) are only actuators. In both the cases of haptic display and force feedback devices, the forces produced by the actuators aim at simulating kinaesthetic sensations within the muscles.

However, force actuators (in haptic display as well in force feedback devices) stimulate not only the internal muscular mechanoreceptors, but also obviously all the tactile ones. Similarly, tactile devices have to be resistant to the penetration of the fingers and thus necessarily stimulate also the deep tissues and the muscular mechanoreceptors. More generally, due to the complexity of the haptic perceptual system, the stimuli received when manipulating the device, whatever it is, integrate always both muscular kinaesthetic and tactile perceptions.

We are confronted here with a first very specific difficulty with the expression haptic devices. Indeed, using a term originally introduced to identify human sensors and/or human sensations in order qualify and categorize devices is not adequate. As evidence, the existing device cannot be efficiently classified according to the various perceptual component of the haptic system: tactile, force or others (pain, etc.).

Another way to overcome the fuzziness of the term haptic device and categorize them that has been proposed is focusing on the scale of the actuating data produced: very small values for tactile devices, and upper scale values for force feedback devices. However, this classification is not more valid. For example, force feedback devices must be able to render accurately very low forces, such as friction forces, with very low residual non-expected forces.

Anyway, there is no bijective relation between the human haptic system and the transducers that aim at acquiring and generating phenomena produced or sensed by the human sensory-motor apparatus. And there is no direct relation between the electromechanical properties of the devices (or further of the system that controls the device and the real or virtual object manipulated through the haptic device) and the subjective properties that can be inferred by the human through his perceptual and cognitive system.

Confronted to the ambiguity between the human senses and the objective data provided by actuators that are always present, Cadoz, Florens and co-workers, accompanied their works on the so-called force feedback devices started in the middle of the 70s, by setting-up a specific terminology [Cadoz et al. 1984a, 1984b].

They propose to call all the haptic apparatus, as defined by Gibson, gestural channel [→ Gestural channel], avoiding the unclear term Haptic. Here, gestural is an integrated term nominating all the mechanical human body activity. The gestural channel declines into gestural action and gestural perception, two expressions that can be associated to technological actuators and sensors without the need to refer to human sensations, perceptions or subjective associations.

Correlatively, they introduced the generic term TGR (in French "*Transducteurs Gestuels Rétroactifs*", in English "Retroactive Gesture Transducer", or also "Responsive Input Devices") [Cadoz and al., 1984]. This expression puts the emphasis on the response to an input. The acronym TGR allows avoiding the term force feedback device which is too much specific and not sufficiently representative of the concepts and the technologies that are implemented by those devices. The advantage of this terminology is to be objective, independent of the human sensing and motor means, and to focus on the true core functionalities of the system:

- The word Transducer (which incidentally is more precise than the buzzword device) addresses the property of fidelity in the signal coding of the physical data;
- The word Gesture indicates that the system is sufficient to be used by human through gesture
- The word Retroactive (which is more precise than the buzzword feedback), addresses the link between what the systems measures (i.e. the signals sensed in response to the human mechanical action via the system sensors) and what the system returns (i.e. the mechanical effect of the actuators, that will be perceived by human haptic perception). It emphasizes also the fact that both these phenomena are supposed to be tightly tied to each other.

The confusion between human sensory-motor system and technical apparatus subsists also when considering sensing functionalities. As a first preliminary remark, it is not usual to put under the umbrella of haptic devices systems that are only sensing systems, i.e. without actuating components. Symmetrically, there is no case in which one speaks only on the motor human apparatus under the term haptics. In experiments that set up directly and only the human motor system, when muscles are directly stimulated to create an illusion of action [Albert et al., 2006], the usual term is *virtual action*.

A third question to discuss is related to the morphology of haptic devices. As a haptic device is built in order to be manipulated by hand or by the body through gesture, and actuators and/or sensors are embedded in their mechanical morphology. Morphologies include two parts: the organisation of the mechanical parts that support sensors and actuators, and the morphologies of the end-effectors themselves. End-effector is a term used in robotics to nominate the part of the robot that manipulates real objects. It is used in haptic device to nominate the part of the device that is manipulated by the user.

Morphologies are as diverse as the actuators or sensors are, and as the part of the body involved in the manipulation is. They vary from exoskeleton carried by part or the whole body, to vis-à-vis manipulated systems of various sizes and mechanical organisation, and from versatile morphologies to fixed morphologies [→ Effector], see also [Burdea et al. 2003]). Indeed, the question raised by the morphological components is of the same nature as the previous questions discussed regarding actuators. There is no necessary bijection between the morphological organisation of the human sensori-motor system (hand, arm, etc.), and the morphology of the haptic device. The morphology of haptic device plays an important role in the physical adaptation of the manipulation to the task. Thus, it must be defined by taking into account, on the one hand the human morphology and on the other the morphology of the performed task.

Finally, we cannot forget that haptic devices are necessarily controlled by an external processes that can be also from different nature: control-command processes in teleoperation systems, computer simulation in virtual reality systems. Problems and questions related to that external processes are discussed in several items: [→ Algorithm] [→ Channel, afferent / efferent] [→ Force feedback device / force properties] [→ Haptic rendering of virtual objects] [→ Mechanical impedance] [→ Simulation] [→ Stability].

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Related items

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